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Research Article

Block Diagram of an Electro Elastic Drive for Nanobiomedicine

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Abstract

In the work the block diagram of an electro elastic drive is calculated for nanobiomedicine. An electro elastic drive is used for nanobiomedicine in scanning microscopy, DNA research, adaptive optics, XYZ micropositioning system, compensation of gravitational and temperature displacements. By using method of mathematical physics, the block diagram of an electro elastic drive is determined for nano biomedicine.

Keywords: Electro elastic drive, Piezo drive, Block diagram, Nanobiomedicine

Introduction

An electro elastic drive is used for nanobiomedicine in nanoposition, DNA research, scanning microscopy, adaptive optics, XYZ micropositioning system, damping vibration [1-21]. The block diagram of an electro elastic drive is constructed for nanobiomedicine [22-59].

Method

The method of mathematical physics is used to determine the of the electroelastic drive using the equation of electroelasticity and the ordinary differential equation. The equation electroelasticity an electro elastic drive [3-43] is written in the general form

$$S_i = \nu_{mi}\Psi_m + s_{ij}^{\Psi} T_j$$

here *i, j, m,* S_i, $\nu_{mi} = d_{mi}$, g_{mi}, $\Psi_m = E_m, D_m$, T_j, s_{ij}^{Ψ} are the indexes, the relative displacement, the electroelasticity coefficient for the voltage or current control, the control parameter in the form the electric field strength or the electric induction, the mechanical field strength and the elastic compliance.

The ordinary differential equation [11-57] for an electro elastic drive

$$\frac{\mathrm{d}^2\Xi(x,s)}{\mathrm{d}x^2} - \gamma^2\Xi(x,s) = 0$$

here $\Xi(x,s)$, γ, x, s, are the Laplace transform displacement, the propagation coefficient, the coordinate, and the transform parameter.

Block Diagram

For the ordinary differential equation for an electro elastic drive its boundary conditions are determined

$$T_j(0,s) = \frac{1}{s_{ij}^{\Psi}} \frac{d\Xi(x,s)}{dx}\bigg|_{x=0} - \frac{\nu_{mi}}{s_{ij}^{\Psi}}\Psi_m(s)$$

$$T_j(l,s) = \frac{1}{s_{ij}^{\Psi}} \frac{d\Xi(x,s)}{dx}\bigg|_{x=l} - \frac{\nu_{mi}}{s_{ij}^{\Psi}}\Psi_m(s)$$

here $l = \{\ \delta, h, b$ for the longitudinal, transverse, shift piezo drives.

The Laplace transform general force

$$F(s)=\frac{\nu_{mi}S_0\Psi_m(s)}{s_{ij}^{\Psi}}$$

Than the general block diagram for distributed parameters of an electro elastic drive with on (Figure 1) is calculated for nanobiomedicine

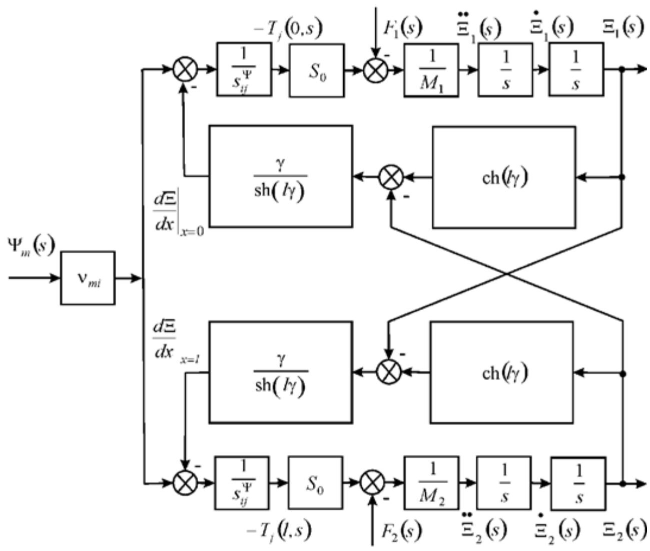

Figure 1: General block diagram for distributed parameters electro elastic drive.

$$\Xi_1(s)=\left(M_1s^2\right)^{-1}\left\{\begin{array}{l}-F_1(s)+\left(\chi_{ij}^{\Psi}\right)^{-1}\\ \times\left[\begin{array}{l}\nu_{mi}\Psi_m(s)-\left[\gamma/\mathrm{sh}(l\gamma)\right]\\ \times\left[\mathrm{ch}(l\gamma)\Xi_1(s)-\Xi_2(s)\right]\end{array}\right]\end{array}\right\}$$

$$\Xi_2(s)=\left(M_2s^2\right)^{-1}\left\{\begin{array}{l}-F_2(s)+\left(\chi_{ij}^{\Psi}\right)^{-1}\\ \times\left[\begin{array}{l}\nu_{mi}\Psi_m(s)-\left[\gamma/\mathrm{sh}(l\gamma)\right]\\ \times\left[\mathrm{ch}(l\gamma)\Xi_2(s)-\Xi_1(s)\right]\end{array}\right]\end{array}\right\}$$

$$\chi_{ij}^{\Psi}=s_{ij}^{\Psi}/S_0$$

here

$$\nu_{mi}=\begin{cases}d_{33},d_{31},d_{15}\\ g_{33},g_{31},g_{15}\end{cases},\quad \Psi_m=\begin{cases}E_3,E_3,E_1\\ D_3,D_3,D_1\end{cases}$$

$$s_{ij}^{\Psi}=\begin{cases}s_{33}^{E},s_{11}^{E},s_{55}^{E}\\ s_{33}^{D},s_{11}^{D},s_{55}^{D}\end{cases},\ \gamma=\left\{\gamma^{E},\gamma^{D}\right.,\ c^{\Psi}=\left\{c^{E},c^{D}\right.$$

The general block diagram of an electro elastic drive with distributed parameters on (Figure 1) is used for nanobiomedicine.

Than displacement matrix

$$\begin{pmatrix}\Xi_1(s)\\ \Xi_2(s)\end{pmatrix}=\left(W(s)\right)\begin{pmatrix}\Psi_m(s)\\ F_1(s)\\ F_2(s)\end{pmatrix}$$

$$\left(W(s)\right)=\begin{pmatrix}W_{11}(s) & W_{12}(s) & W_{13}(s)\\ W_{21}(s) & W_{22}(s) & W_{23}(s)\end{pmatrix}$$

here

$$W_{11}(s)=\Xi_1(s)/\Psi_m(s)=\nu_{mi}\left[M_2\chi_{ij}^{\Psi}s^2+\gamma\,\mathrm{th}(l\gamma/2)\right]/A_{ij}$$

$$A_{ij}=M_1M_2\left(\chi_{ij}^{\Psi}\right)^2s^4+\left\{(M_1+M_2)\chi_{ij}^{\Psi}/\left[c^{\Psi}\mathrm{th}(l\gamma)\right]\right\}s^3+$$
$$+\left[(M_1+M_2)\chi_{ij}^{\Psi}\alpha/\mathrm{th}(l\gamma)+1/\left(c^{\Psi}\right)^2\right]s^2+2\alpha s/c^{\Psi}+\alpha^2$$

$$W_{21}(s)=\Xi_2(s)/\Psi_m(s)=\nu_{mi}\left[M_1\chi_{ij}^{\Psi}s^2+\gamma\,\mathrm{th}(l\gamma/2)\right]/A_{ij}$$

$$W_{12}(s)=\Xi_1(s)/F_1(s)=-\chi_{ij}^{\Psi}\left[M_2\chi_{ij}^{\Psi}s^2+\gamma/\mathrm{th}(l\gamma)\right]/A_{ij}$$

$$W_{13}(s)=\Xi_1(s)/F_2(s)=$$
$$=W_{22}(s)=\Xi_2(s)/F_1(s)=\left[\chi_{ij}^{\Psi}\gamma/\mathrm{sh}(l\gamma)\right]/A_{ij}$$

$$W_{23}(s)=\Xi_2(s)/F_2(s)=-\chi_{ij}^{\Psi}\left[M_1\chi_{ij}^{\Psi}s^2+\gamma/\mathrm{th}(l\gamma)\right]/A_{ij}$$

Than displacements two ends of the longitudinal piezo drive

$$\xi_1=d_{33}UM_2/(M_1+M_2)$$
$$\xi_2=d_{33}UM_1/(M_1+M_2)$$

At PZT drive d_{33} = 0.4 nm/V, U = 75 V, M_1 = 0.5 kg, M_2 = 2 kg this displacements are determined $\xi_1 + \xi_2$ = 30 nm, ξ_1 = 24 nm, ξ_2 = 6 nm.

Let us consider the block diagram of the piezo drive with first fixed end and elastic inertial load at the voltage control.

The equation direct piezo effect [3-43]

$$D_m = d_{mi} T_i + \varepsilon_{mk}^E E_k$$

here ε_{mk}^E - the permittivity.

Than k_d direct coefficients

$$k_d = \frac{d_{mi} S_0}{\delta s_{ij}^E}$$

The Laplace transform voltage for first feedback is obtained

$$U_d(s) = \frac{d_{mi} S_0 R}{\delta s_{ij}^E} \dot{\Xi}_2(s) = k_d R \dot{\Xi}_2(s)$$

The equation of the reverse piezo effect [3-43]

$$S_i = d_{mi} E_m + s_{ij}^E T_j$$

Than Laplace transform general force of drive

$$F(s) = \frac{d_{mi} S_0 E_m(s)}{s_{ij}^E} = \frac{d_{mi} S_0 U_C(s)}{\delta s_{ij}^E} = k_r U_C(s)$$

$$k_r = k_d = \frac{d_{mi} S_0}{\delta s_{ij}^E}$$

The Laplace transform force for second feedback at the voltage control

$$F_l(s) = \left(C_e + C_{ij}^E + k_v s\right) \Xi_2(s)$$

here k_v - the coefficient of viscous friction.

Than block diagram for lumped parameters the piezo drive and fixed end, elastic inertial load and the voltage control is determined on (Figure 2)

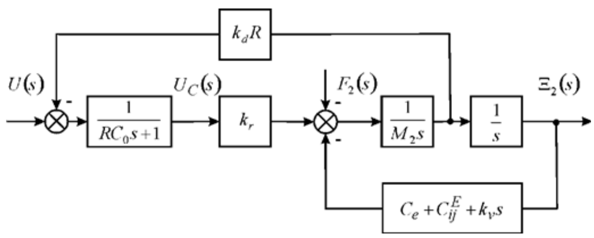

Figure 2: Block diagram for lumped parameters piezo drive.

Than its transfer function

$$W(s) = \Xi_2(s)/U(s) = k_r \big/ \left(a_3 p^3 + a_2 p^2 + a_1 p + a_0\right)$$

$$a_3 = RC_0 M_2 \text{,} \; a_2 = M_2 + RC_0 k_v$$

$$a_1 = k_v + RC_0 C_{ij} + RC_0 C_e + Rk_r k_d \text{,} \; a_0 = C_e + C_{ij}$$

For $R = 0$ function

$$W(s) = \Xi_2(s)/U(s) = k_{31}^U \big/ \left(T_t^2 s^2 + 2T_t \xi_t s + 1\right)$$

$$k_{31}^U = d_{31}(h/\delta) \big/ \left(1 + C_e / C_{11}^E\right)$$

$$T_t = \sqrt{M_2 \big/ \left(C_e + C_{11}^E\right)} \text{,} \; \omega_t = 1/T_t$$

At PZT drive = 1 kg, C_e = 0.2×10^7 N/m, C_{11}^E = 1.4×10^7 N/m its parameters are founded T_t = 0.25×10^{-3} s, ω_t = 4×10^3 s^{-1}. At PZT drive d_{31} = 0.2 nm/V, h/δ = 20, C_e/C_{11}^E = 0.14 its coefficient is determined k_{31}^U = 3.5 nm/V.

Discussion

In the work the method of mathematical physics is used to determine the block diagram of the electro elastic drive using the equation of electro elasticity and the ordinary differential equation. The displacement matrix drive is determined.

Conclusions

The general block diagram for distributed parameters an electro elastic drive is calculated for nanobiomedicine. The displacements two ends of the longitudinal PZT drive are determined. The block diagram for lumped parameters the piezo drive and the voltage control is obtained. The parameters PZT drive are founded.

Conflict of Interest

None.

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